OBSERVATIONS AND NUMERICAL SIMULATIONS OF WESTERN BOUNDARY CURRENT IMPACT ON THE CAPE HATTERAS CONTINENTAL MARGIN

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LONG-TERM GOALS

The goal of this project is to understand the impacts of the Gulf Stream on the shelf circulation of the Cape Hatteras continental margin and aspects of the exchange of water mass with slope and Gulf Stream water and the interactions of the Middle and South Atlantic Bight shelf regimes.

OBJECTIVES

The objectives are to understand the role that Gulf Stream characteristics play on the dynamics and circulation of the shelf region near Cape Hatteras. These features include meanders and shifts in mean position and configuration as it detaches from the continental margin at Cape Hatteras. This involves assessing the contributions of the Gulf Stream processes to shelf transports and exchanges versus local and remote wind and buoyancy-driven flows.

APPROACH

The approach is to utilize an extensive set of moored and hydrographic data from a two year long experiment of the Cape Hatteras margin (Berger *et al.* 1995) and a time-dependent finite element coastal ocean circulation model that allows realistic representation of key coastline and bathymetric features. Combining the analyses of the observations and model results allows us to differentiate between Gulf Stream effects and locally and remotely forced wind-effects on the shelf circulation, the resulting on- and offshore transports, and the exchanges between the Middle and South Atlantic Bights.

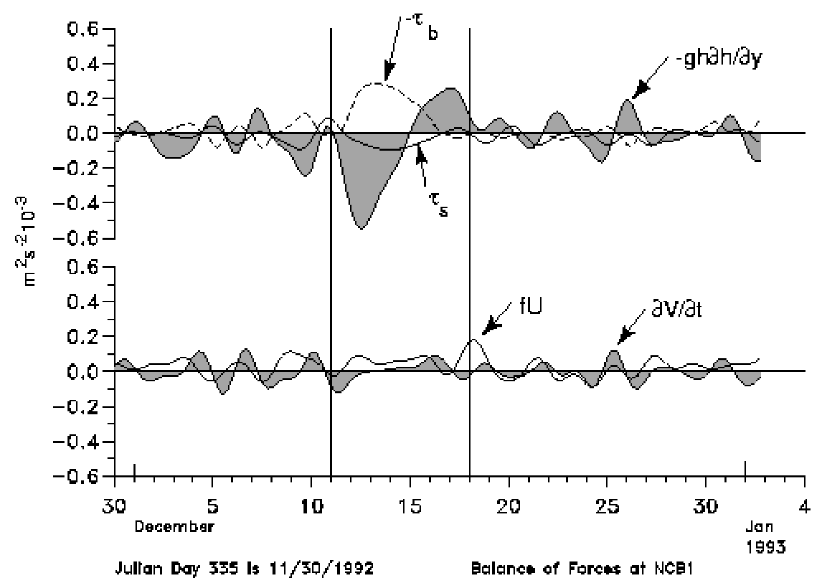
WORK COMPLETED

The data analysis of the experimental data has been completed and incorporated into the numerical modeling effort. Data analysis has concentrated on the dynamics of the shelf and the influence of Gulf Stream meanders on cross-shelf and along-shelf flows.

RESULTS

1. <u>Momentum Balances.</u> The flow field on the shelf has competing influences in the 2 to 10 day frequency band from Gulf Stream (GS) meanders, wind forcing and longshore pressure gradients. Wind forcing dominates in the winter months when the GS front surfaces and is narrow. Flows over most of the shelf are coherent with the local wind field over the southern Mid-Atlantic Bight. In summer, the contrast between the GS and adjacent shelf waters is much weaker and GS meander induced motions can dominate the outer, middle and occasionally the inner shelf in northern Raleigh Bay. Longshore sea-level differences are caused by the differing wind response north and south of the Cape where there is an abrupt change in the direction of the coastline and shelf. The Mid-Atlantic Bight is also more strongly influenced by southward propagating continental shelf waves, whereas the South-Atlantic Bight show a predominantly local wind-forced response. However, GS meanders are also a direct influence on the pressure gradient over the narrow shelf south of Cape Hatteras. These mechanisms can generate large pressure gradients which force large southward (~50-100 cm/s) longshore flows which advect cooler fresher Mid-Atlantic Bight water into the nearshore regions of the Carolina Bays.

The balance of forces of large longshore pressure gradients around Cape Hatteras have been investigated, and an example for a major storm in December 1992 is shown in the figure below.

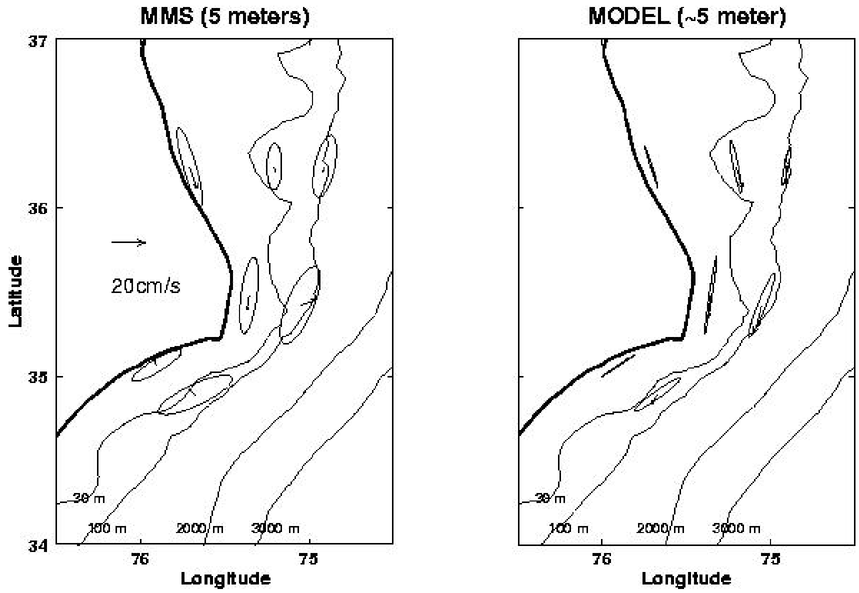


At B1 (Inshore Mooring North of Cape Hatteras) balance is between ($-gh\partial h/\partial y$) longshore pressure gradient and ($-\tau_b$) bottom friction for a major southward flow event between Dec 11 and 18, 1992.

The primary balance is between the bottom stress and the longshore pressure gradient at the nearshore mooring (B1) just north of the Cape. Local surface windstress is of lesser importance in forcing the large southward flows during this exceptional event. The generation of longshore pressure gradients is partly the result of coastline geometry, large scale wind fields north and south of the Cape, continental shelf waves propagating southwards along the mid-Atlantic shelf, and Gulf Stream influences near Cape Hatteras. The importance of these forcing mechanisms on the circulation, have been shown to be a function of season. In summer, the narrow shelf is less isolated from the Gulf Stream and meanders are significantly coherent with sea-level at Cape Hatteras. A presentation was made on these topics at the Spring 1998 Ocean Science meeting in San Diego and a manuscript is in preparation.

2. Mass Balances. Volume transports along the continental shelf near Cape Hatteras, North Carolina have been calculated from a mooring array in place from February, 1992 through March, 1994. Several features of interest have been identified. Alongshelf transport is seen to be primarily convergent over all timescales addressed by these data; from daily variability to the two-year mean. However several episodes of divergent alongshelf transport are identified, existing in each instance from one to eleven days, and constituting 10% of the record length. Evidence for non-negligible onshore flow during these periods exists in the moored current meter data. Drifters deployed as part of the same experiment did not identify such onshore flow, but were not deployed during the periods of prolonged alongshore divergence. There is a strong seasonal signal in the alongshelf transport and transport convergence at Cape Hatteras that seems to be associated with the seasonal wind variability. In addition, 30-60 day period variability is seen in the alongshelf convergence. This variability is not associated with the wind field variability, but instead is correlated to variability in the offshore position of the Gulf Stream. Not surprisingly, periods of large convergence along the shelf correspond to periods when the Gulf Stream is nearest the shelf break. Furthermore, EOF analyses indicate a higher correspondence between Gulf Stream position and alongshelf *transport convergence* than between Gulf Stream position and alongshelf *transport* at Cape Hatteras. This suggests that the Gulf Stream may be directly influencing export processes at the shelf edge, as opposed to simply modulating alongshelf transport at Cape Hatteras.

3. Seasonal Signal. A comparison of the variance ellipses of near-surface currents at seven stations is shown on the next page. The observations and model results show that shoreward of the 70m isobath the flow in the MAB for the 1 Oct 1992 to 30 March 1993 time-period is southward into the SAB. South of Cape Hatteras the magnitude of the southward component decreases, with the observed currents showing a tendency for onshore flow. (Note that the mean signal in this last case may not be significant since the variance is much larger than the mean.) The semi-major axes of the observed and model ellipses are aligned with the local isobaths and the magnitudes are of the same order. Near the Chesapeake Bay outflow greater variance is observed probably due to discharges not included in the model simulations. The semi-minor axes are underestimated by the model relative to the observations reflecting the cross-isobath variability likely due to the presence of the Gulf Stream, baroclinic effects associated with the cross-shore gradient in the temperature field, and other unresolved motions.



Observed and modeled current variance ellipse parameters at seven locations in the Cape Hatteras region over the time period 1 Oct 1992 to 31 Apr 1993. Ellipse orientation is in degrees relative to true East.

IMPACT/APPLICATIONS

The combined use of data analysis and model studies should help in the development of a more quantitative understanding of the dynamical processes of shelf regions adjacent to western boundary currents. The shelf off Cape Hatteras is perhaps the best example of a confluence zone between major ocean gyre systems. Other shelf- and shelf-edge regions will benefit from a better description of the physical oceanography of confluence zones, particularly as affected by large-scale boundary current influences and associated intra-shelf exchange processes. The ability to quantitatively capture current and transport events will define the level of detail required in meteorological and upstream- or remotely-forced conditions in modeling coastal environments. This has implications for the planning and maintenance of long-term monitoring stations and their use in systems predicting (or nowcasting) circulation on continental shelves.

TRANSITIONS

The data analysis results have been used in the NOAA funded South Atlantic Bight Recruitment Experiment (SABRE) to validate the use of the numerical model in examining along- and cross-shore transport mechanisms during the shelf-phase of the menhaden life cycle. The transport of menhaden larvae from the Middle to South Atlantic shelves and the nursery ground in the estuaries is important to the success of the fishery. Three papers and parts of a doctoral dissertation have resulted from this work.

RELATED PROJECTS

SABRE - The present ONR project has provided model-validation for the circulation model of the shelf-phase of the South Atlantic Bight Recruitment Experiment. Model predictions have supported the notion of menhaden spawning areas in the Middle Atlantic Bight supplying larvae to the Carolina estuaries and sounds. The modeling results obtained by examining the MMS data set have been key to understanding the offshore phase of the menhaden larval stages.

Our studies and understanding of the dynamics of the shelves in the Middle and South Atlantic Bights and related model enhancements are being used in formulating hypotheses and research strategies in the NOPP-funded South Atlantic Bight Synoptic Ocean Observing System (SABSOON; H. Seim, PI). The goals of SABSOON include near real-time modeling of the physical oceanography of the shelf-edge region off Georgia and South Carolina using data assimilation techniques.

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